UDC 621.316.718:[621.352.6.546.185-325]

DEVELOPMENT OF ON-SITE FUEL CELL POWER UNITS: CONTROL SYSTEM

Akira Furusawa
Hisanobu Yokoyama

1. INTRODUCTION

This article describes operation procedure and the features of the control system for on-site fuel cell power unit and also explains control process at start-up, continuous operation and shutdowun of the power units.

2. OPERATION METHOD

The operation of the plant is basically automated as shown in *Fig. 1*. Under the operation procedure of "start-up" or "shutdown" the next procedure follows automatically with no input commands after finishing the procedure of startup or shutdown. Under the other operation procedure, operation command shall be input or the plant is automatically shutdown to keep itself safe when abnormal operation conditions are detected by sensors attached to the plant.

Operation commands can be input to the plant from Programable Operation Display (POD) equiped to the plant. POD shows operation procedure being under way and shows the causes of emergency shutdown when the shutdown happens. Operation commands can be input by touching keys on POD. POD has a registered panel as shown in *Fig. 2*.

Fig. 1 Operation method

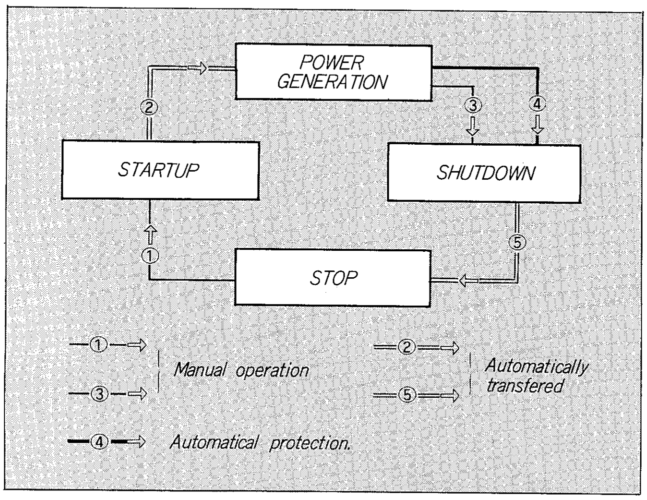
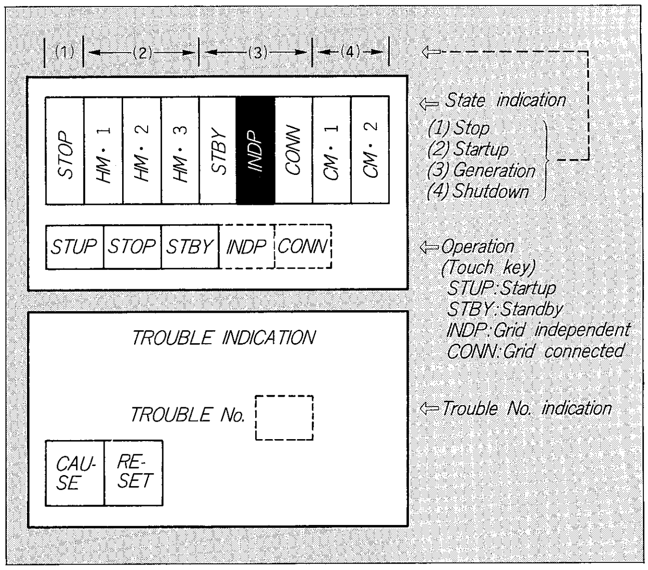


Fig. 2 Display on controller



3. FEATURES

The plant is similar to a chemical plant because it includes a steam reforming system. The system has chemical reactions which occur at a certain limited temperature and pressure ranges.

The valves for inflamable gases has the functions to make the plant safe even when power fault happens.

In addition to the above the plant has to quickly respond to power demands. It requires quick hydrogen generation in the reformer because hydrogen consumption in the stack is propotional to the electric current generated in the fuel cell stack. This is a very much different point from a general chemical plant. Flow rates of air, fuel and steam should respond quickly to power demand signal because their consumptions are also propotional to the output current of the stack. The flow rate control signals are shown in *Fig. 3*. The control signals for heat exchangers are omitted in *Fig. 3*.

4. STARTUP OF THE SYSTEM

During startup of the plant, the fuel processing system

Fig. 3 Control signal

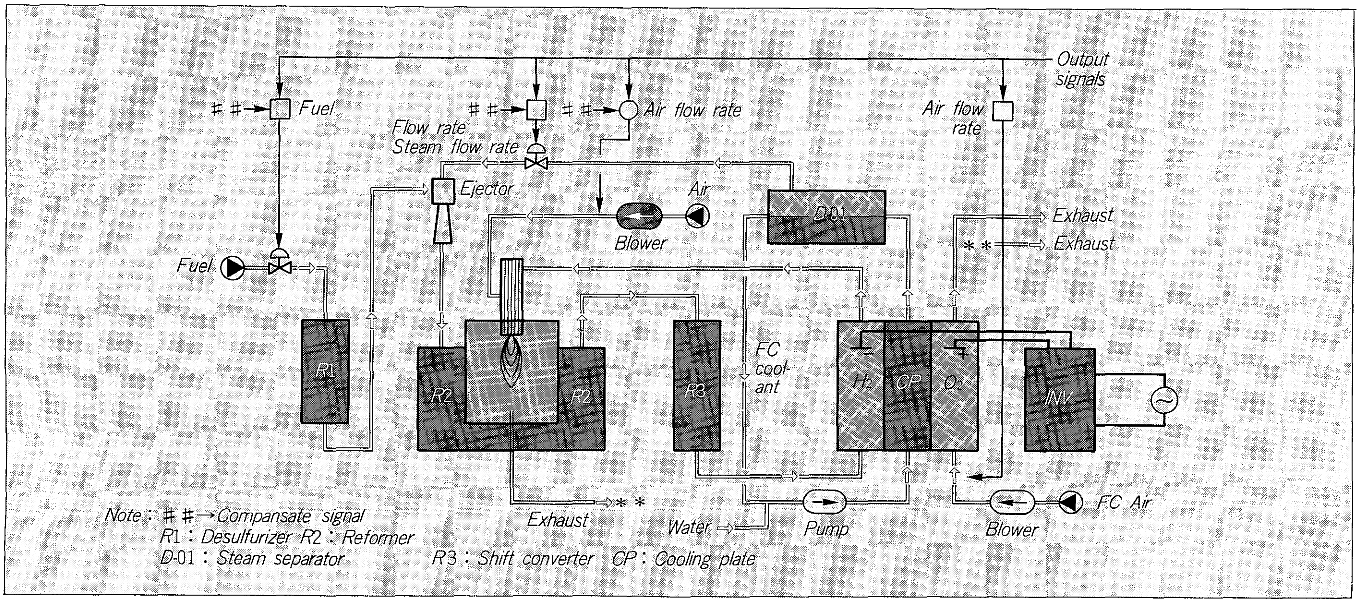
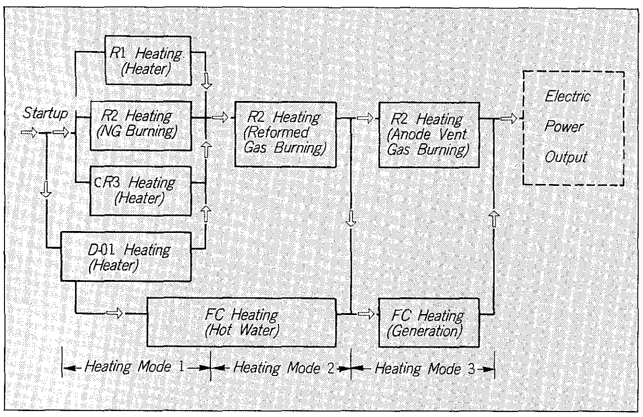


Fig. 4 Startup process



(including desulfurizer, steam generater, and shiftconverter) and the stack are heated up to their operation temperatures. Desulfurizer, shiftconverter and steam generator are heated by electric heaters. Reformer is heated by gas burner. The stack is heated by supplying hot water from steam generator to the cooling plates installed in the stack.

Figure 4 shows the operation steps of the plant from startup to power generation. Reformer has no reforming reaction during heating mode 1 because of its low temperature. In heating mode 2, reformer supplies reformed gas to its burner to keep its reforming temperature. In heating mode 3, the stack is heated up to its normal operation temperature with heat generated in itself and heaters. The electric power for the heaters are supplied internally from the stack. Reformer burner uses anode vent gas out of the stack as its fuel.

5. OUTPUT POWER GENERATION

After heating up every component in the plant to its normal operation temperature, provided that every utility is prepared, the plant can generate electric power to be send to outside loads by selecting its internal switching positions as shown in *Fig. 5*.

6. POWER SENDING

Direct current generated in the stack is converted to alternative current with inverter. The plant has two ways to send power as shown in *Fig. 6*. One is grid independent mode and the other is grid connected mode.

Under the grid independent mode, the output voltage and frequency are controlled with internal device to set their values. Output power of the plant responds to outside loads with limitations.

Under grid connected mode, output power shall be set and has the same voltage and frequency as the grid. The three selectable connection points between the plant and the grid are shown in *Fig. 6*. The point S-1 is included in the plant. The points S-2 and S-3 shall be prepared at site. At each point the plant side PT and the grid side PT are prepared to measure voltage and frequency of each side. After frequency synchronization and voltage adjustment, the selected switch is turned on to operate the plant at grid connected mode.

7. SHUTDOWN

When the plant is shutdown, all inflamable fuel included in the plant is purged with nitrogen to keep the plant safe and to protect reforming catalyst degradation. Air in the stack also is purged with nitrogen. Power charged in the stack is discharged by connecting discharge resistance between the positive terminal and the negative terminal of the stack. The stack is cooled down to protect performance decay which can be caused by keeping high temperature. The fuel processing system is protected from air penetra-

Fig. 5 Power circuit

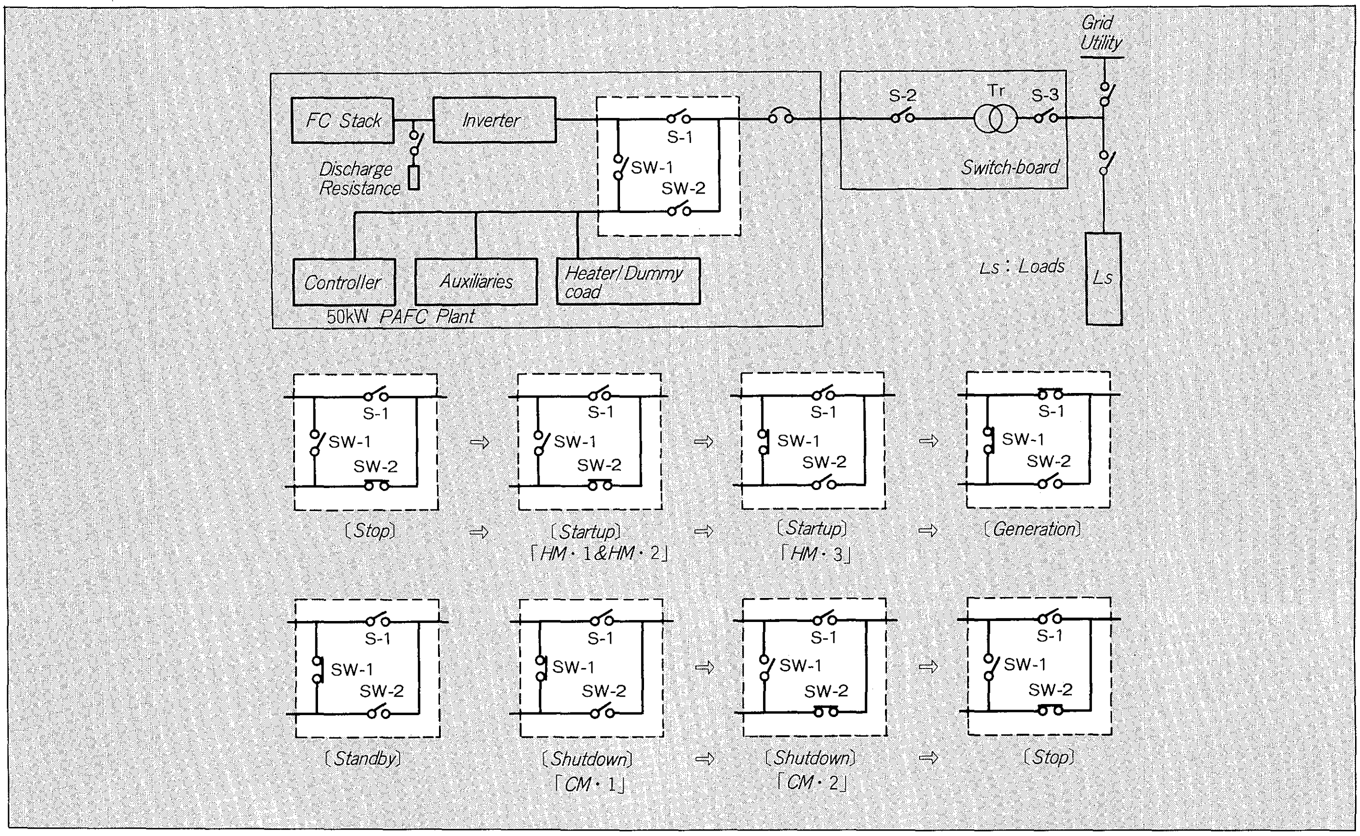
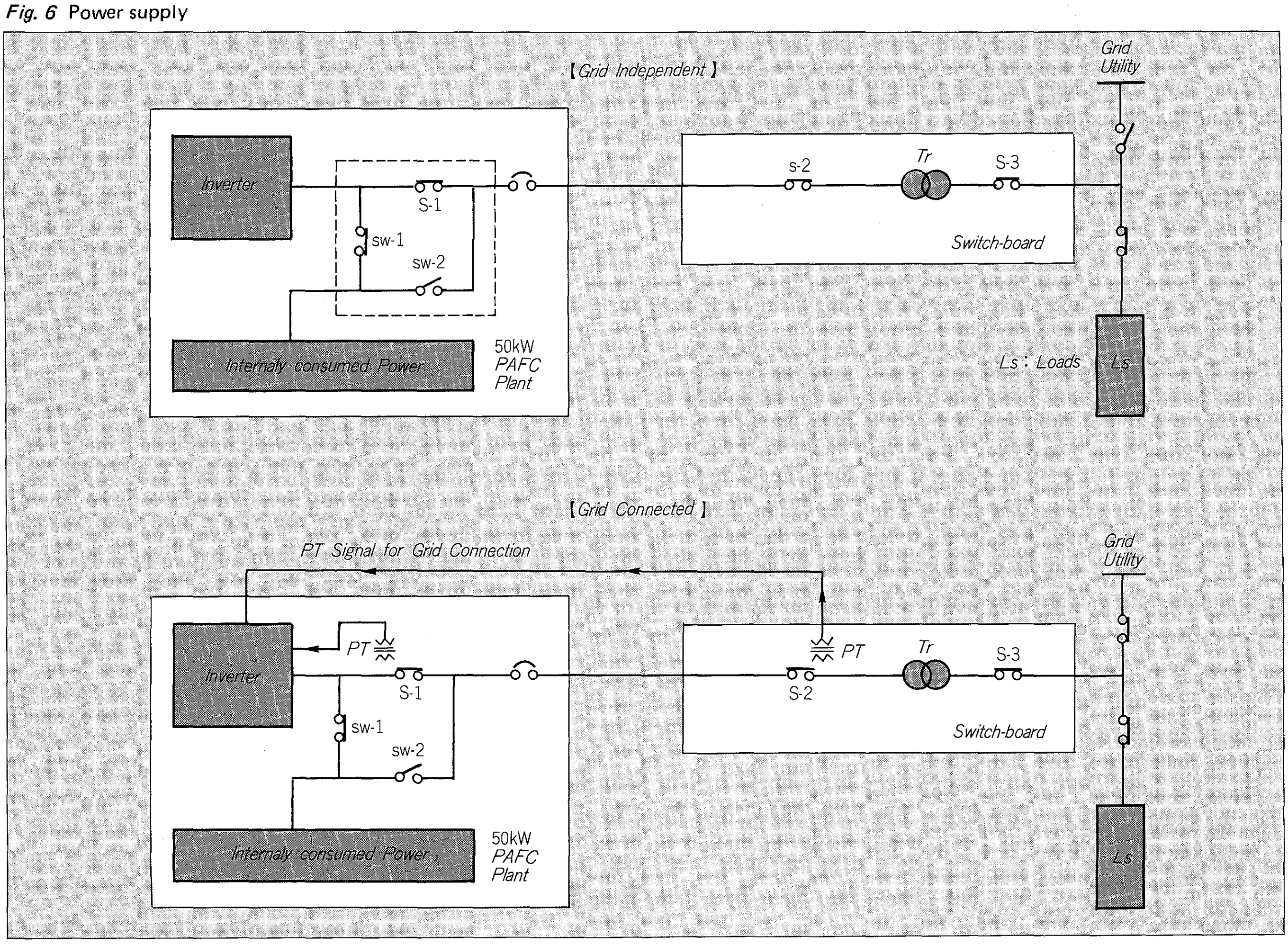


Fig. 6 Power supply



tion by usually supplying a very small amount of nitrogen to the system. In the normal shutdown procedure, the stack is cooled down to the set temperature while generating electric power and then is purged with nitrogen.

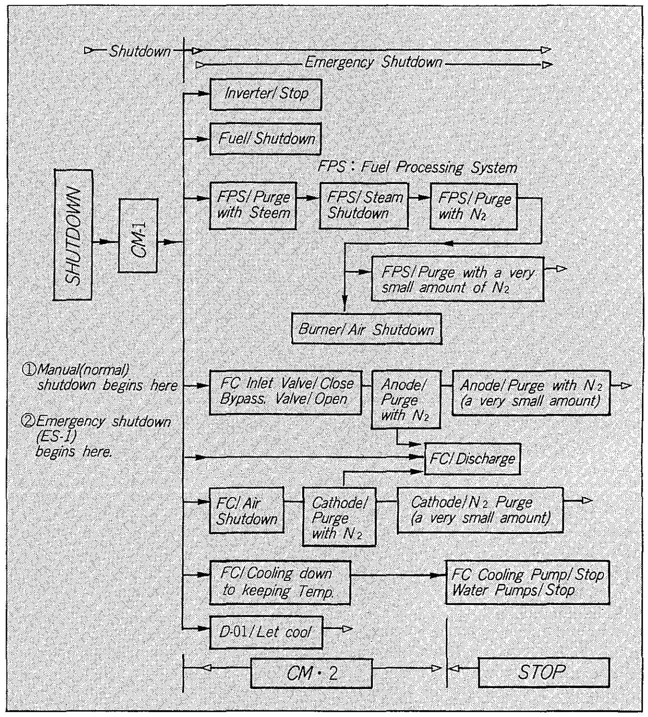
8. PROTECTION ON THE SYSTEM OPERATION

The plant has many sensors to detect operation conditions. Fuel processing system has temperature and burner failure sensors. Fuel cell has temperature, voltage and current sensors. Steam and water lines have pressure and water level sensors. If any abnormal condition is detected by the sensors, the plant automatically is shutdown to protect and to keep itself safe. *Figure 7* shows the shutdown process with protections.

The plant has two compartments. One is low temperature compartment in which the controller of the plant and the power conditioner including inverter are installed because they are electronic devices and should be kept cool. The compartment also has forced ventilation system to keep cool and to prevent from penetration of inflamable gases into the compartment.

The other is relatively high temperature compartment in which high temperature components such as the fuel processing system and the stack are installed. Since they makes the compartment temperature relatively high though they are thermally insulated and they include inflamable gase, the compartment has also forced ventilation system to cool itself and to avoid accumulation of leaked gas when gas leakage happens.

Fig. 7 Shutdown process



9. CONCLUSION

We are making an effort on realization of an appropriate programming function for reliable performance of the control system with securing the features of every components. Hereafter, we will make improvement of the control system in cooperation with the related fields.